TREPHINATION BY DRILLING IN ANCIENT MEXICO

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A LITTLE more than 100 years have passed since Paul Broca's first description of cranial trephination.[1] In this time the learned opinions concerning the reasons for the operations, the techniques employed, the rates of survival, and other relevant aspects have changed markedly. It is now generally accepted that most cranial trephinations were undertaken for therapeutic reasons. There are many obvious maladies which would be cured or relieved by trephination;[2] fracture of the skull appears to be the commonest of these. Not surprisingly, fractures of the skull and trephinations are often associated with populations that employed weaponry of the smashing type, in contrast with the stabbing and slashing types.[3, 4, 5] It is also accepted that most prehistoric trephinations were successful, to the extent that the patient survived the operation itself. Estimates of survival necessarily depend on the correct identification of healing. Such identification is complicated by the existence of a large number of causes that produce openings in the skull which occasionally are indistinguishable from trephination.[6, 7, 8] Moreover, it is clear that a restricted number of techniques were employed in the areas where prehistoric trephination was common: viz., Western Europe and Highland South America.

The two most common techniques used by prehistoric cranial surgeons were scraping and cutting. Scraping involves the gradual removal of the layers of cranial bone until the inner table has been opened and the dura is exposed. The resultant evidence consists of fairly large openings or depressions, usually oval, in the skull.[9] Cutting or sawing was also common; several subroutines were practiced. In some cases a round piece of bone was removed by means of a beveled, circular incision, the hole being larger in the external table of bone than in the internal table. A more dramatic technique was practiced mainly in the central highlands of Peru.[10] It consisted of four cuts arranged in "tic-tac-toe" pat-

tern. The center was removed, leaving a rather large square or rectangular opening. The same method was employed on a skull from the Lachish site in Israel,[11] a rare exception to the otherwise localized distribution of this technique.

Other techniques, less commonly employed, include chiseling, punching, and drilling. A chiseling technique is known from the Aymara of highland Bolivia, who use a stone hammer and a rusty nail which has been flattened,[12] and Tello demonstrated that a circular series of holes in a Peruvian skull was probably produced by hammering copper rods into the skull.[13] The use of a circular drill, such as is employed in modern trepanning, is very rare in prehistoric material, as is evidence of any type of drill-trephination. The recent discovery of a trephined skull from Mexico and some previously published data from Mexico[14] point to the southern Mexican highlands as an area which in prehistoric times possessed an independent technique of cranial surgery. In the present essay I shall discuss this skull and shall present some inferences which bear upon the interpretation of prehistoric cranial surgery in general.

In the autumn of 1972 excavation of a residential area of the archaeological site of Monte Alban, Oaxaca, yielded 25 human skeletons. The site, designated MA72, is located approximately 1 km. from the center of the main plaza. One of the burials, MA72-1, is of special interest because it had been subjected to trephination of a type rarely seen in prehistoric skeletal series. Burial MA72-1 is of the Late Classic, Monte Alban IIIB period, and would be dated at approximately 650 A.D. The burial consists of the cranium, mandible, and fragmenatry postcranial skeleton of a male, probably aged about 30 years at the time of death. The sagittal suture is closed endocranially, but the coronal and occipital sutures are open. Dental attrition is very slight, there being much less wear than expected for the estimated age of the individual. Observable lesions are restricted to the teeth and supporting alveoli, in that both the mandibular and maxillary alveoli are abscessed and a single tooth is carious. The skull is not deformed nor are the teeth mutilated.

The skeleton was found in an extended supine position and was oriented approximately north-south, with the head toward the south. Objects found with the skeleton include one ceramic vessel, an obsidian blade, painted and unpainted stucco fragments, and some dog bones. The vessel and obsidian blade probably represent grave offerings whereas the other objects may have been part of the fill.

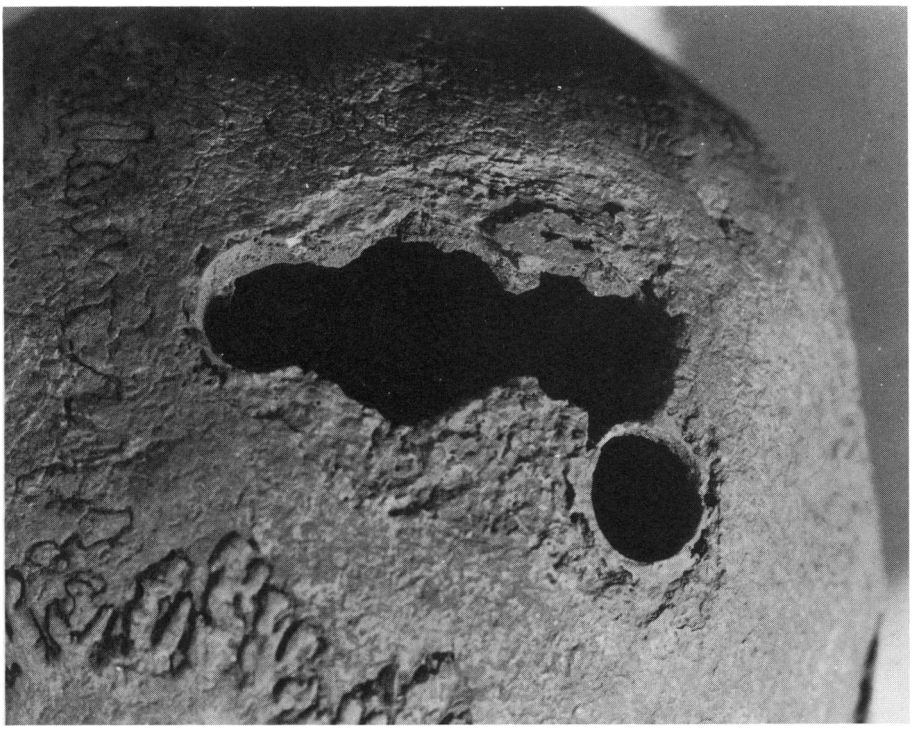

Fig. 1. The trephined area of the right parietal of skull MA72-1, bordered medially by the sagittal suture and inferiorly by the occipital suture. Note the roughened area of osteitis surrounding the perforations and the small cut immediately lateral to the completely circular opening. A small piece of the inner table of the skull can be seen in the hole closest to the sagittal suture.

The area of interest on the skull is the posteromedial quadrant of the right parietal bone (Figure 1). There are four circular openings in the parietal, although only the most medial and the most inferior openings are undoubtedly due to surgical procedures. The edges of these two openings are distinct and solid, unlike the indistinct edges of the two middle holes. The openings range in diameter from 12.8 to 20.5 mm., the three continuous perforations forming an orifice 47.2 mm. long. The two most distinct openings (medial and inferior) have identical diameters of 12.8 mm.

There is an approximately triangular area of roughened bone which

follows in outline the configuration of the series of openings. Dr. T. D. Stewart has pointed out some of the difficulties in the interpretation of antemortem trephination and has noted the significance of areas of osteitis on the outer table of bone, corresponding in shape to that of the openings.[15] The examples of osteitis cited by Stewart differ from MA72-1 in that most of Stewart's examples are of angular trephinations, with clearly visible, correspondingly angular areas of roughened or scarred bone. Like the few nonangular examples mentioned by Stewart, MA72-1 shows an ill-defined area of roughened bone which surrounds the opening. Stewart argued that the angular configuration of the osteitis was due to removal of the scalp; it may well be that the ill-defined area of osteitis in skull MA72-1 is due to the reflection and subsequent replacement of the scalp, rather than its removal. Immediately lateral to the complete inferior opening is a small cut mark. This mark corresponds to the most lateral extension of the roughened outer table of bone, and probably was made during reflection of the scalp prior to the trephination.

The appearance of the openings suggests a number of explanations. The smooth circular shape of the medial and lateral holes, with their vertical walls and slight lipping of the interior margin, would be expected from drilling. The thin shelf of bone, which gives the holes a slightly cupped appearance, might then represent the point at which the drilling was discontinued in order to avoid injury to the brain. This would then imply that the drill bit was shouldered to prevent the point from penetrating too deeply or that drilling stopped prior to penetration of the inner table and that the operation was finished by cutting away the inner table. There is evidence that the drill bit was tubular, not shouldered, as will be seen later. Cutting may thus have been utilized to complete the operation, although it is also a distinct probability that this slight lip of bone is due to the process of healing.[16] The nearly identical diameters of the two openings would then suggest that the same drill bit was used and that the two holes were made at the same time. If this is the case, the two intervening openings are more difficult to explain, as they differ greatly in morphology from the medial and inferior openings. Is it possible that the osteitis was severe enough to destroy the bone completely, leaving two approximately circular openings? Or did it weaken the bone, which decomposed after death? The very thin edges of the largest

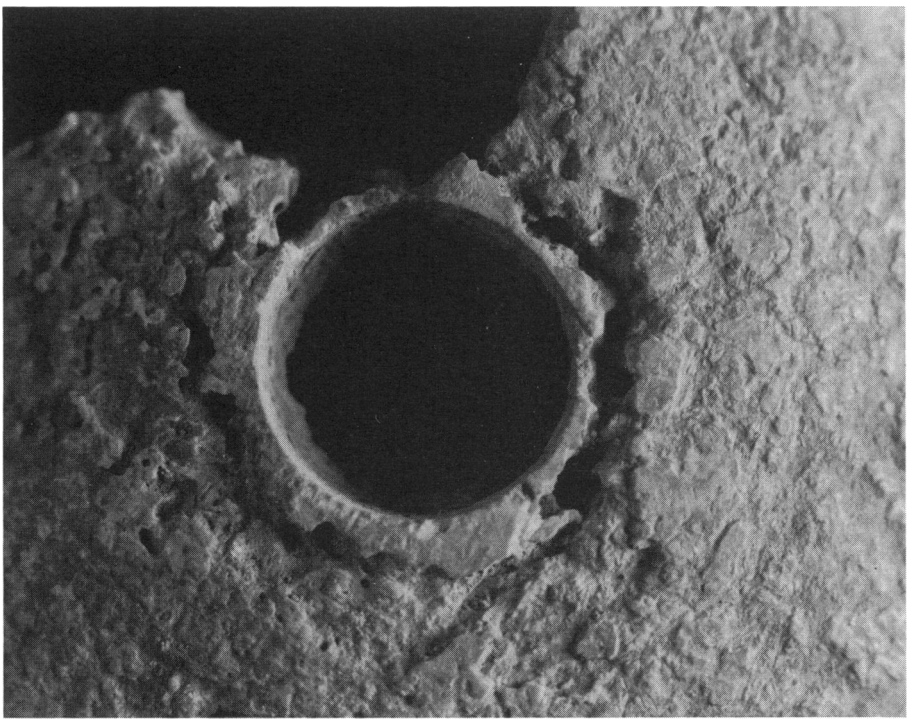

Fig. 2. This close-up view of the inferior hole illustrates the collar of bone surrounding the opening, and the open spaces between this collar and the adjacent parietal bone. The cut mark is the straight line immediately to the right of the circular opening.

hole would make the latter explanation plausible, but the most lateral opening is different, in that its lateral wall is thick. Here the outer table was little involved and it appears that the bone had been removed surgically.

A close inspection of the complete inferior trephination raises some interesting questions. As can be seen from the photograph (Figure 2), the ring of bone which surrounds the orifice is free of the adjacent bone along the superior edge. There are also small perforations between the bone that surrounds the orifice (the "collar") and the adjacent parietal bone, especially along the medial and lateral sides. This "collar" of bone surrounding the inferior orifice is also of different consistency than the adjacent bone; it is somewhat more compact

and of lighter color. The sharpness of the outline of the inferior orifice argues against a prolonged postoperative survival. The numerous reported examples of supposedly healed trephinations are similar in that where healing has been claimed the openings have smooth, beveled edges regardless of the technique of perforation. However, the walls of the two most distinct openings do not show a well-defined diploic structure. Closure of the diploe is recognized by several authors as sound evidence of postoperative healing[17-20]—assuming, of course, that the diploic structure is open in unaffected parts of the skull.

If it is assumed that death occurred soon after the drilling of the two sharp-bordered holes, a number of questions are raised. If there was a short period of survival—days or hours—why is there such extensive osteitis of the outer table? What caused the small perforations immediately adjacent to the inferior opening? Why would the ring of bone around this opening be impervious to the destruction that is apparent in the adjacent bone? Is the smoothness of the "collar" of bone around the inferior opening due to healing, or does it represent the original, uninvolved outer table? I am assuming that the osteitis was due to postoperative infection, and not that it was the reason for the operation. The distinctness of the inferior opening, with its well-defined and apparently normal collar of bone, is evidence that the operation took place on healthy bone.

We can turn to the literature for examples which may clarify the nature of the techniques used at the MA72 site. As mentioned above, cutting, sawing, and scraping were the primary techniques used by prehistoric cranial surgeons. The ancient Peruvians used cutting and sawing as the primary technique, and practiced scraping also.[21] The European examples are seen as representing primarily two techniques: scraping and cutting.[22] Drilling is virtually unknown in the European and Peruvian areas, at least prehistorically. A single skull from Mallorca presents a series of small, circular holes in the parietal bone which appear to have been drilled, although the author favors a "push-plough" technique.[23] The procedure in which a series of small holes is bored in a circular pattern—the intervening bone then being cut from hole to hole—is known from Roman times, among certain medieval Arab groups,[24] and in North African groups of the past century.[25] A Peruvian skull with this series of holes is also known, but it was shown that the holes were probably made by punching, not drilling.[26]

The only sound evidence of prehistoric drilling comes from highland Mexico—in fact from the same archaeological complex that yielded the MA72-1 skull. In a survey of the known Mexican examples of trephining, Romero[27] discusses nine skulls, five of which were excavated from Monte Alban. Of these five skulls, two have perforations which clearly were produced with a drill. Burial IV-40, a Late Classic (Monte Alban IIIB-IV) adult female, presents a circular, vertical-sided opening in the left frontal bone, just above the orbit. The hole is 18.5 mm. in diameter, and is surrounded by an "incision" or crack in the outer table, which Romero believes may be a fracture.[28] The similarity of this feature to the ring of bone surrounding the inferior hole in the MA72-1 skull is obvious, although the "collar" is much larger in the IV-40 skull than in the MA72-1 skull.

The other drilled skull from Monte Alban is III-19.[29] This fragment of skull is important for an understanding of the drilling technique used at Monte Alban. The cranial fragment is from a young adult female, of the same period as the previous example. The fragment shows a completed, circular perforation at the bregma, 19 mm. in diameter. Adjacent to this perforation is a circular groove in the right parietal, representing an unfinished trephination. The groove, surrounding a column of untouched bone, indicates that a tubular drill was used. The unfinished opening has a diameter of 16 mm., indicating that two different instruments were used.

The three other examples from Monte Alban appear to have been subjected to scraping or cutting. One of these, burial IV-48,[30] shows a small, approximately circular opening along the sagittal suture. It is relatively straight-sided, as if it had been opened by cutting rather than scraping. This example may suggest the technique used to make the two rough-edged holes in the MA72-1 skull.

Another example of the drilling technique may be that described by Lumholtz and Hrdlicka.[31] Lumholtz discovered the skull of a female in a cave in southern Chihuahua, the skull having a circular opening in the anterior right parietal. The hole has vertical walls and a "lamella" of bone around the base of the opening, as was noted in the MA72-1 skull. Hrdlicka felt that the bone showed signs of healing, and Romero agrees that "the photographs accompanying the study confirm that the perforation is healed."[32] The skull is generally accepted as belonging to the late Postclassic period, and would thus greatly

extend the range of known examples of per-Columbian drilling as a technique of trephining. The claim that the skull is actually pre-Columbian is not, however, convincing. Because a spindle whorl of a type not observed among the Tarahumara was found "among the bones" of the three individuals in the burial cave, Lumholtz and Hrdlicka stated that "it is indeed possible that the skeleton may be pre-Columbian."[33] This is certainly not a strong statement about the skull's pre-Columbian date, and Lumholtz and Hrdlicka offer a number of reasons to doubt this early date. The three bodies were not buried, but had simply been placed within the cave on the floor; this was the customary practice among the Tarahumara.[34] Also, the authors noted that the skeletons were accompanied by a few pottery vessels "of the ordinary Tarahumare [sic] type," and "the cranial walls still contain some animal matter, they are still somewhat fatty to touch, and retain some odor."[35]

In addition to the nine skulls described by Romero,[36] there are three skulls or skull fragments bearing evidence of trephination from the Preclassic site of Tlatilco, in the Valley of Mexico.[37] One of these skulls (Burial 165) has a rather large, approximately circular opening which appears to have been made by scraping, as the edges of the hole seem beveled.[38] The second example from Tlatilco, Burial 191, is a parietal fragment with a circular perforation. This example is not illustrated, nor does the description provide a clear indication of the technique of trephining. The third skull, Burial 106A, has a circular perforation in the left frontal bone, immediately superior to the superciliary arch. The bone just below the perforation has been broken away and only the top half of the perforation is visible. The walls of the hole are described as "perfectly smooth,"[39] but it appears from the photograph that the opening in the external table of bone is larger than the internal opening, giving the hole a beveled appearance.[40] While this last example may represent a drilling operation, the others are more likely to be due to scraping or cutting, and it would appear that even the last example was produced with a technique somewhat different from that employed at Monte Alban 1,000 to 1,500 years later.

Romero also discusses a trephined skull from Preclassic Tlatilco, which was trephined with a scraping technique,[41] and brings to four the number of trephined skulls from the Tlatilco area of the Valley of Mexico. This would appear to be the earliest evidence of cranial sur-

gery in Mexico and indicates that Tlatilco also was in effect a center of surgical experimentation. It well may be that one or more of the Tlatilco skulls was drilled in much the same manner as the Monte Alban skulls and may thus have been their precursor.*

Given the questionable age of the skull described by Lumholtz and Hrdlicka, equivocal nature of at least some of the Tlatilco examples, and the paucity of examples of cranial drilling elsewhere in the world,[42] it appears that this form of experimental cranial surgery was a unique feature of Late Classic Monte Alban. The fact that none of the skulls which were drilled bear evidence of extensive healing may indicate that the procedure was not as successful as the more "traditional" methods of scraping and cutting. Incidentally, both scraping and cutting were being practiced at Monte Alban,[43] and one of the drilled skulls, III-19, appears to have been scraped in the same area where the drilled openings are found. I believe that the MA72-1 skull was also subjected to more than one technique of trephining. It appears that the MA72-1 skull was trephined by cutting and drilling, but it is not clear whether these two techniques represent two separate operations. If we assume that the surgeon probably would not use two different techniques in one operation, we are left with the problem of determining which technique was used first. Neither the roughened outline of the two central holes nor the smooth, circular outer holes is typical of healed trephination, yet the closed diploe of the two latter holes and the osteitis appear to be evidence of postoperative healing. Could the peculiar form of the two most circular holes be due to the presence of "plugs" in the drilled holes? Pieces of the drill itself may have been placed in the openings, and the bone would have begun the process of healing around these plugs.

Such a technique could explain the strange combination of osseous surfaces which offer contradictory evidence of healing. According to this interpretation, the medial and inferior holes would have been drilled with a tubular drill after the original reflection of the scalp. Pieces of the drill could have been inserted into these openings and the scalp

*Since writing this paper, I have been able to see two of the three Tlatilco examples referred to above. Burial 165 has not been trephined, but is instead a good example of a circular fracture; the individual was obviously hit with a pointed object. The skull of Burial 106A probably has been drilled, but the morphology of the hole and its position lead me to believe that the drilling was postmortem. The primacy of Monte Alban as *the* Mesoamerican center for cranial surgery is thus reinforced. More significantly, four additional trephined skulls have been found at Monte Alban, bringing the total to 10.

replaced. After the operation, either infection set in or a reaction to herbal applications occurred, resulting in osteitis. A second operation followed, in which two openings were cut into the area of osteitis between the original perforations. The final openings may well have caused the death of the patient, since there was no evidence of healing around these two holes.

One of the major difficulties with this interpretation is that the insertion of foreign objects into trephined openings is virtually unknown. Replacement of removed bone is reasonably common, but I am aware of only two accounts, both ambiguous, of holes being plugged with foreign objects According to Margetts,[44] "bark, banana leaf and sea shell were used also for plugging or dressing the trepan hole" among some Polynesian groups. Coconut shell was also used, but again it is unclear whether the hole was plugged or covered. Similarly, Bandelier[45] described a Peruvian as having been trephined; after the operation the man "wore a piece of gourd inserted into the orifice." While Moodie[46] and Stewart[47] doubt the existence of such postoperative techniques, the use of plugs remains a distinct possibility. This is perhaps especially so in the Monte Alban area, which appears to have been an area of independent surgical experimentation.

There is a tendency to view non-Western medicine as being based primarily on magico-religious foundations, with little or no empiricism in technique or intent, and we are reluctant to regard the preliterate medicine man as capable of practising neurosurgery. Yet abundant evidence exists to prove that primitive trephination was indeed empirical in its basis and that some techniques were successful. *Most* prehistorical trephinations were successful, and *most* of them were accomplished by scraping or cutting circular or ovoid openings. Other techniques were rarer and less successful, as judged by the amount of postoperative healing. The drilled skulls of Monte Alban number only three, and two of these show no healing around the trephinations. Only the latest skull, MA72-1, shows evidence of healing, and this appears to have been brief. In the absence of evidence to the contrary, it appears that Late Classic Monte Alban was the site of a unique if unsuccessful surgical technique. Although many sites scattered throughout the Valley of Oaxaca were occupied when the ceremonial center at Monte Alban was in use, no trephinations are known from the sites in the floor of the valley.

If the rarity of the drilling technique may be explained on the basis of its failure as an empirical means of relieving cranial maladies, the question remains why such techniques appeared at all, as does the question of why the technique is restricted to the southern highlands of Mexico. Dental mutilation may offer an answer to both of these questions. Mutilation of the teeth was rather common in pre-Hispanic Mexico. The techniques were primarily of two types, filing and incrustation.[48] Incrustation involves the drilling of a hole into or through the tooth, the hole then being filled with an inlay. Romero[49] suspects that the drilling technique, which first appears in the Middle Formative or Preclassic period (900-600 B.C.), was derived from jewelry-making techniques. Could there be a connection between dental drilling and that seen in the three skulls from Monte Alban?[50] There is circumstantial evidence which supports this association. First, some of the drilling used in the making of jewelry was done with tubular drills; even jade was drilled in this fashion. Second, dental drilling and cranial drilling are Mexican. While dental mutilation is known from North and South America, none of these examples are incrustations.[51] There is certainly no association between dental mutilation and trephination in South America, and the rare South American examples of dental mutilation may well be traceable to Mexico. Similarly, the Andean highlands may have been the source of diffusion for some of the Mexican techniques of trephination, but not the drilling technique. In fact, the unique character of the drilling, together with the lack of the South American "tic-tac-toe" technique in Mexico, would argue against such diffusion. The fact that both Mexico and Peru offer examples of scraped and cut skulls is meaningless in terms of diffusion, since the same techniques were used wherever successful trephination was practiced. Finally, if any one of the Tlatilco skulls was in fact drilled, such an example would have occurred at roughly the same time that dental drilling began, in the Middle Preclassic period.

In summary, this recently discovered skull from Monte Alban increases the evidence of a surgical technique independent of those reported from other parts of the New World. Further, it appears that the drilling technique may have been adapted from similar techniques used in jewelry making and dental alteration. The known examples of drilling are restricted in time as well as space, as all known

examples are from the Late Classic period. The drilling technique was used on both males and females, and the skeletons of those operated on were not accompanied by grave goods indicative of special status. As excavation proceeds in the Valley of Oaxaca, we may find a wider distribution of trephination, but current evidence indicates that drilling was strictly a Monte Alban technique. In fact, with the exception of one skull from Monte Negro,[52] Monte Alban stands as the center of cranial surgery for all of the Southern Highlands of Mexico and has the highest concentration of trephined skulls north of South America.

Acknowledgments

Excavation of the MA72 site was carried out by Dr. Marcus Winter, in accordance with Concesión Arqueológica No. 16/71 of the Instituto Nacional de Antropologia e Historia. Dr. Winter's generosity and hospitality are most gratefully appreciated. Research and travel funds were provided by the State University of New York Research Foundation.

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